Tropical clear-sky OLR variability studies from a simple model

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Motivations

- Clear-sky OLR (OLRc) sensitivity to water vapor has been widely studied over the last decades (Sinha and Harries 1997, Spencer and Braswell 1997, Huang et al. 2007, Dessler et al. 2008).

- However, many of these studies have focused on the sensitivity over oceans and not over the different kind of tropical/subtropical land surfaces.

- OLRc sensitivity studies to water vapor are essentially performed on mean states of the atmosphere or through the kernel approach (Soden et al. 2008). We want to develop a different strategy based on an exhaustive representation of the OLRc field with a simple model in order to bring out robust features of the dependence of OLRc to the humidity fields and their characteristics at different time scales.

Outline

I – Hypotheses and framework for the simple OLRc model
- I – 1. TS sensitivity
- I – 2. FTH sensitivity
- I – 3. The two-parameter statistical model

II – OLRc sensitivity studies at interannual time scales
- II – 1. Synthetic OLRc field
- II – 2. Variability experiment on FTH
- II – 3. Evaluation of FTH time variablity in two GCMs

III – The two-parameter model at climate time scales
- III – 1. IPSL-CM5 RCP runs
- III – 2. Climate sensitivity in the simple model framework

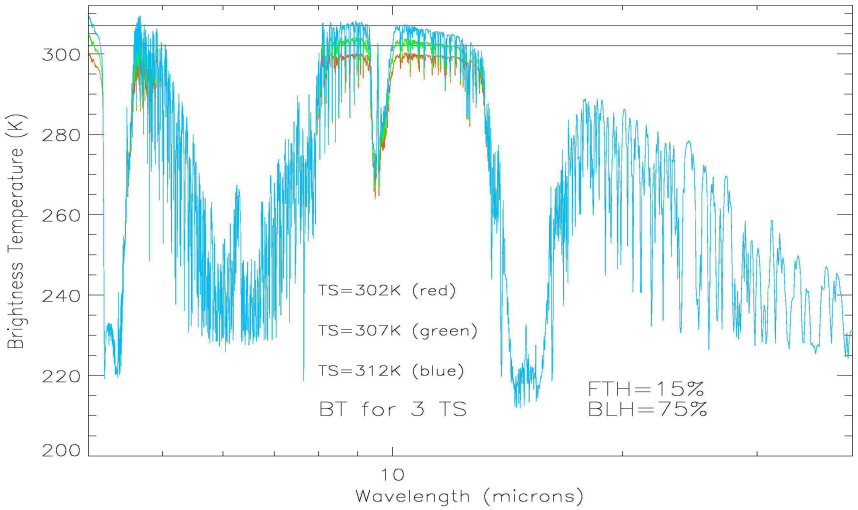
IV – Conclusion and outlooks

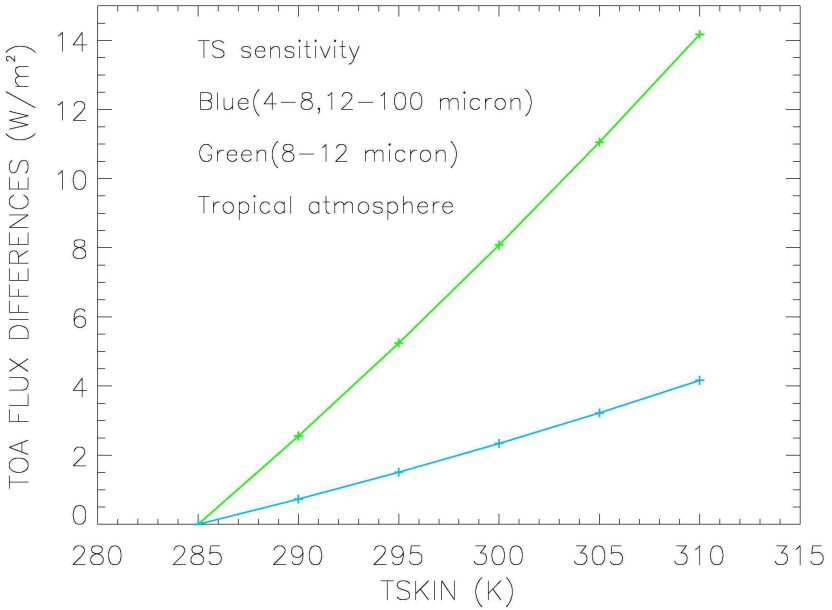
I – Hypotheses and framework

I – 1. OLRc sensitivity to TS

- For all the IR radiation calculations we use the spectrally resolved MODTRAN® radiative transfer model (1 cm^-1).

- OLRc window (8-12 µm) flux is essentially sensitive to the Surface Temperature (TS) for a Tropical/Subtropical profile.



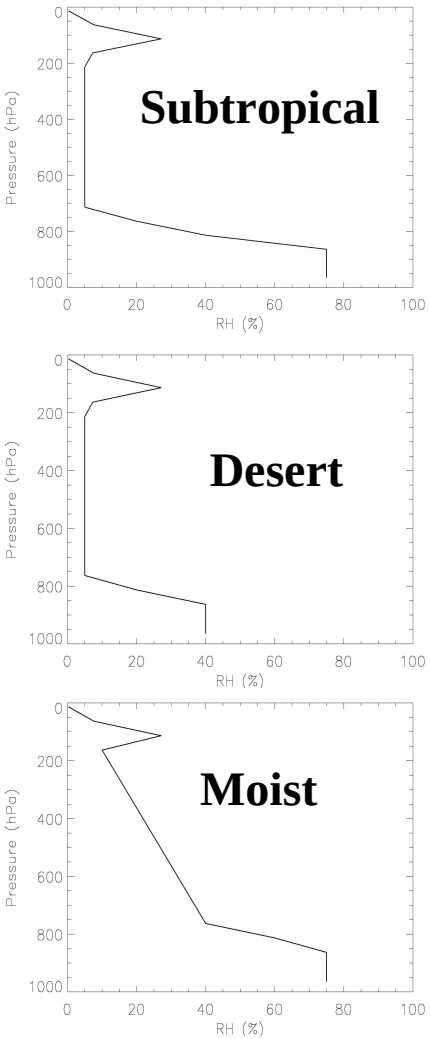


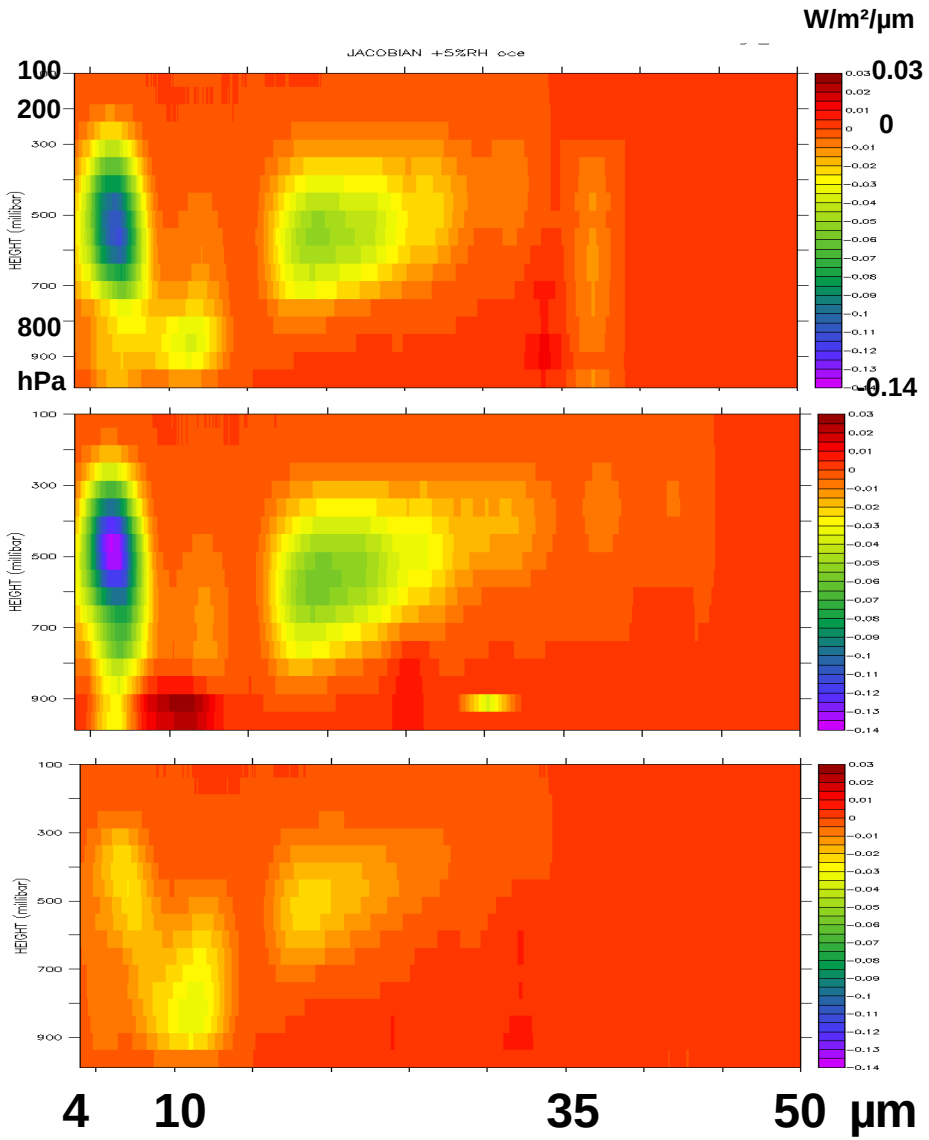
I – Hypotheses and framework

I – 2. OLRc sensitivity to RH

- OLRc spectral jacobians to Relative Humidity (RH) for three idealized profiles: subtropics, desert and moist.

- OLRc is mainly sensitive to the Free Troposphere Humidity (FTH) between 800 et 200 hPa. The moist profile is also sensitive to the window in the lower layers of the atmosphere.



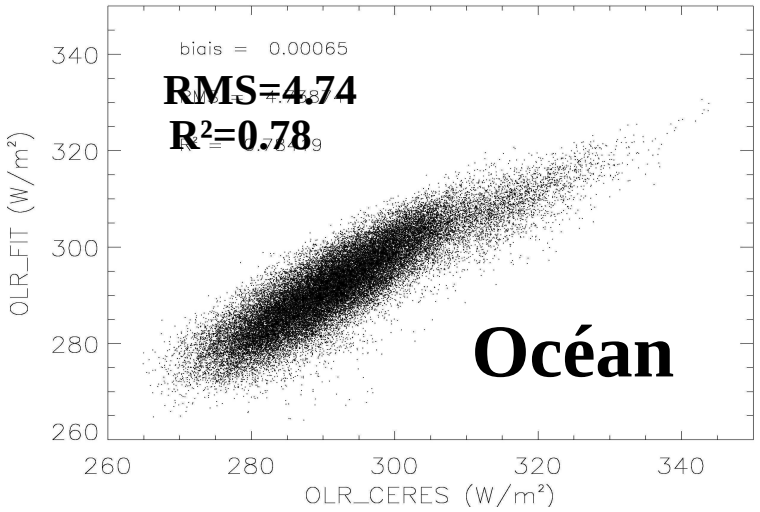


I – Hypotheses and framework

I – 3. Definition and validation of the simple OLRc model

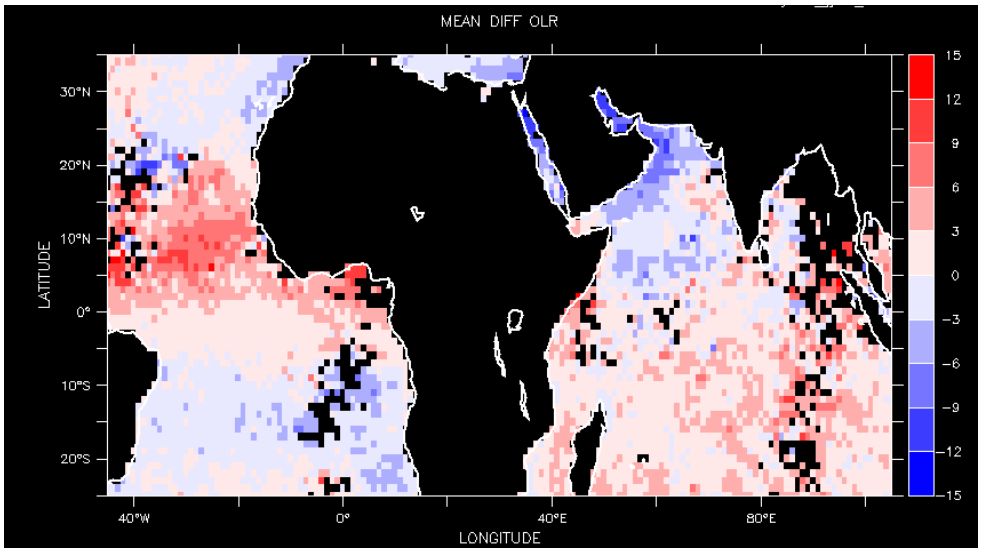
$$OLRc = a \cdot TS + b \cdot \ln(FTH) + c$$

- We perform a bilinear regression of the model on nighttime collocated CERES-SSF (OLRc/TS) and METEOSAT (FTH) data. The a, b and c coefficients are determined for three different types of surface: **Ocean, Land and Desert**.



- Statistics are satisfying, we consider the model accurate enough to estimate **nighttime OLRc** at small space-time scales with TS et FTH fields.

(top-right) Scatterplot between the data and the fit and (bottom-right) mean differences between the fit and the CERES data for JJA (2002-2003).



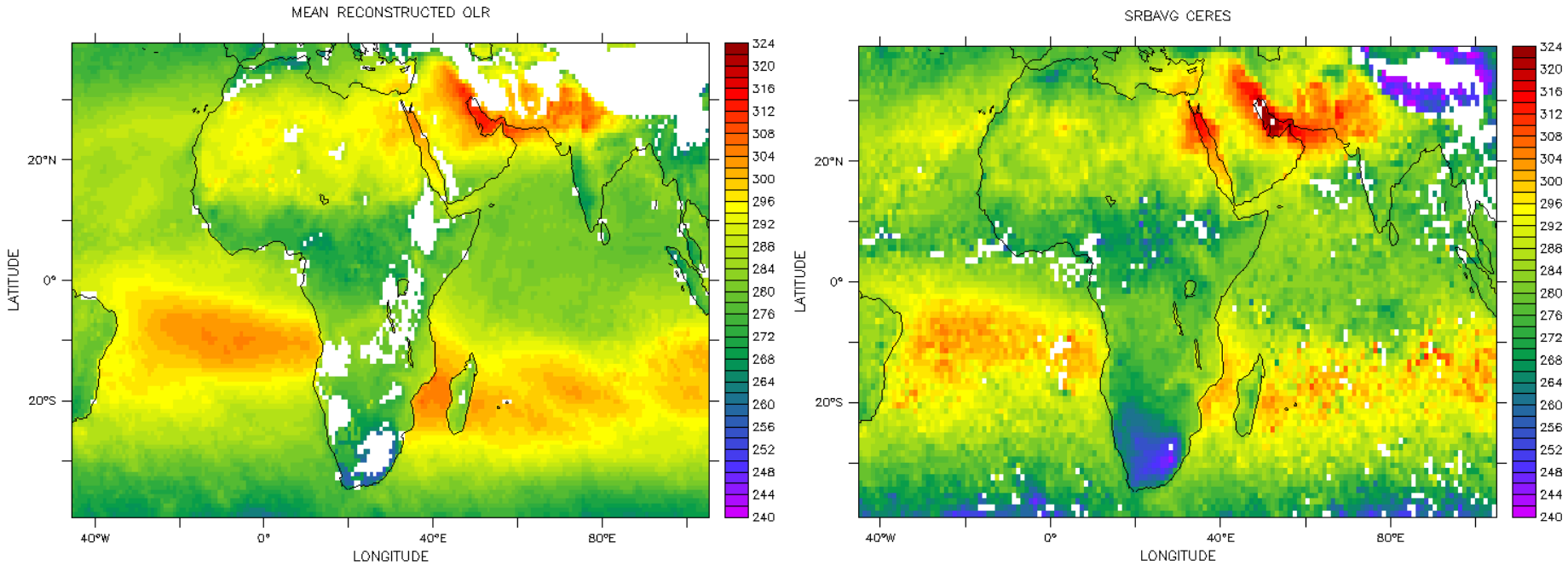
I – Hypotheses and framework

I – 3. Definition and validation of the simple OLRc model

- OLRc monthly mean field: (left) nighttime mean OLRc from the two-parameter model and (right) the equivalent field from CERES-SRBAVG for june 2004

Two-parameter model OLRc
(FTH METEOSAT + TS ERAI)

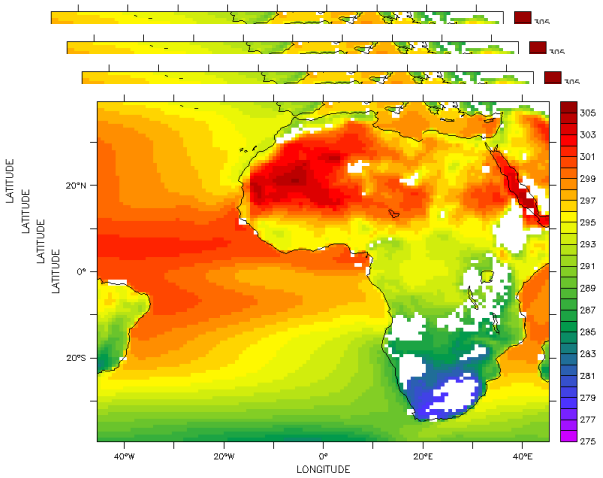
SRBAVG-GEO CERES data



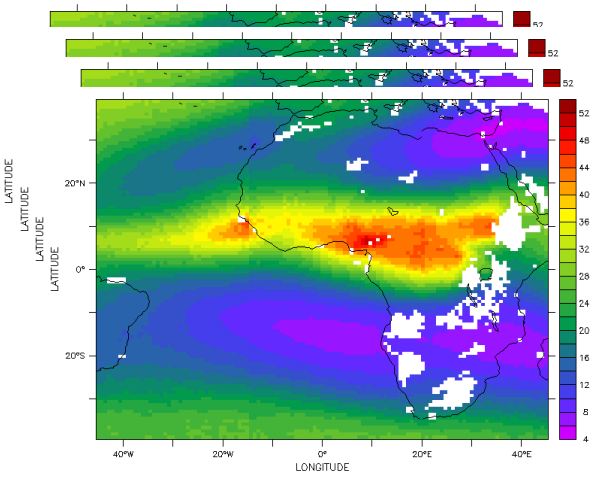
II – OLRc sensitivity studies

II – 1. Synthetic OLRc field from TS and FTH

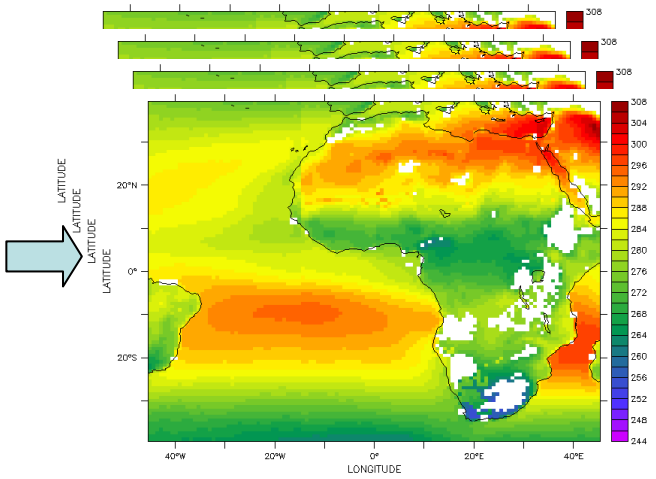
- We build synthetic OLRc fields with one estimate per night from METEOSAT FTH data and TS from ERA-I. We have 20 years of these two fields which allow us to compute OLRc for JJA and DJF seasons for interannual studies or to estimate the mean annual cycle of OLRc over two decades.



TS field



FTH field

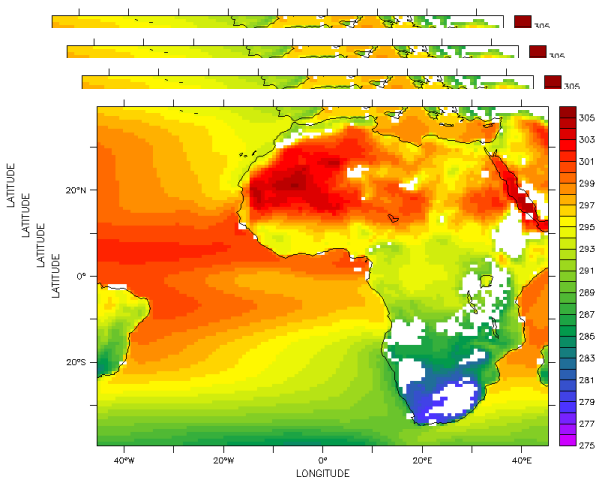


OLRc synthetic field

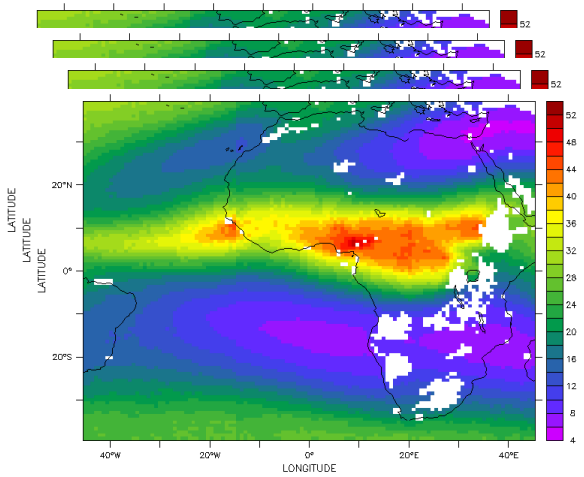
II – OLRc sensitivity studies

II – 1. Sensitivity experiments to time variability

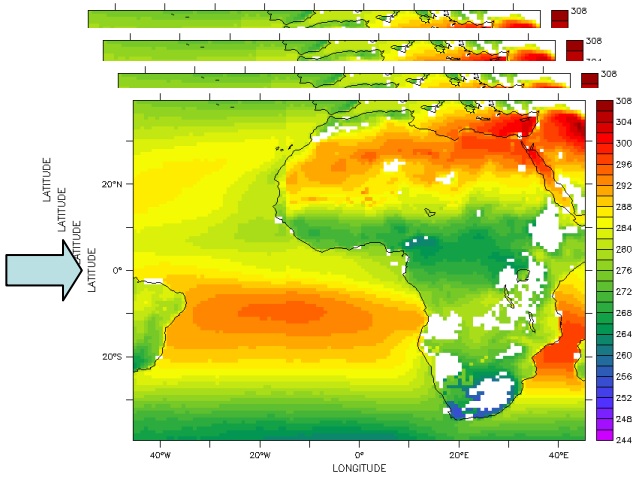
- We replace each nighttime FTH value by its mean climatology value of the regime considered.



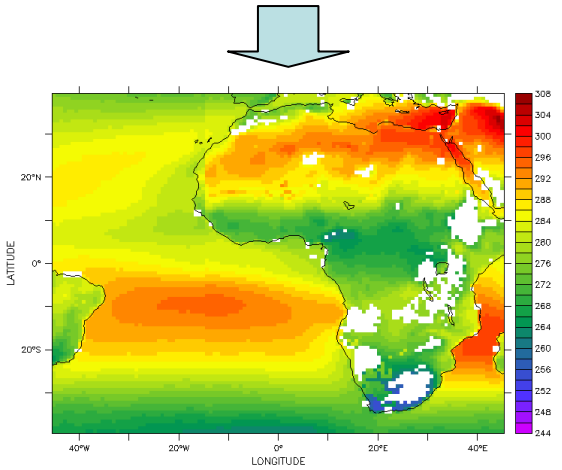
TS field



FTH field



- The mean OLRc is then computed with the full time variability fields :



Mean OLRc synthetic field

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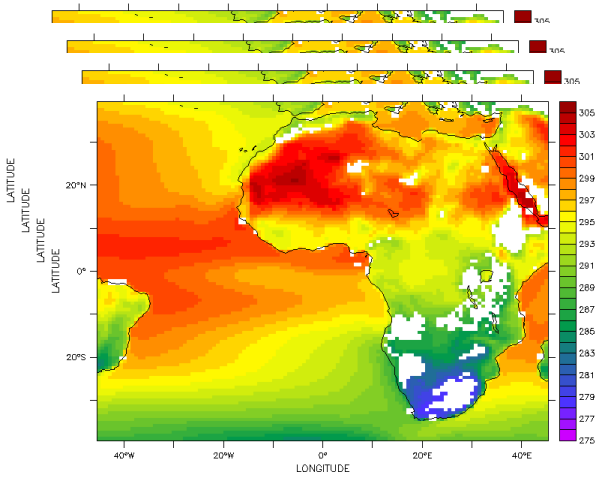
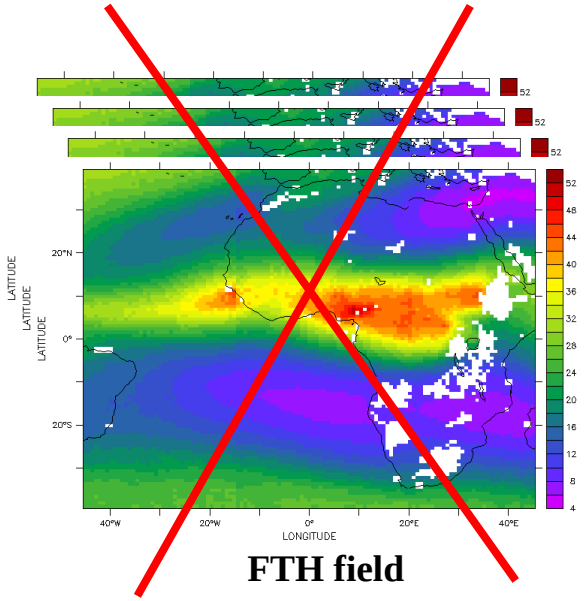
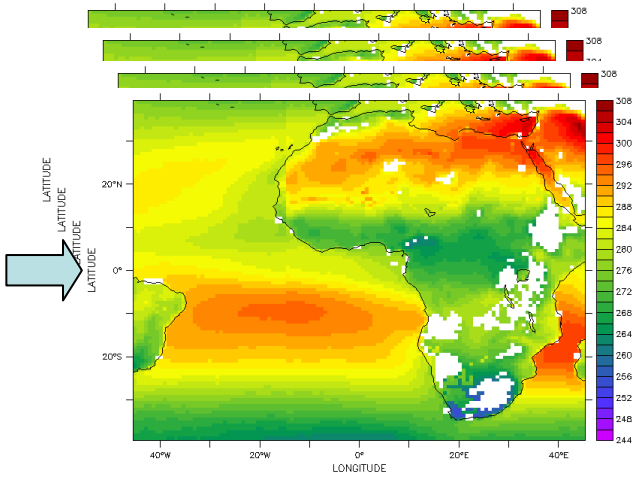


TS field



FTH field



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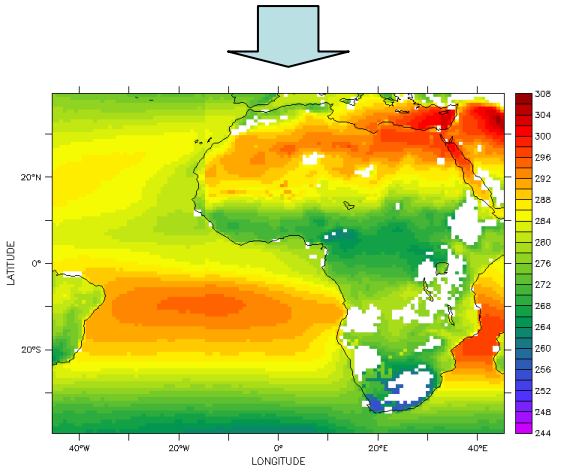

Mean OLRc synthetic field

II – OLRc sensitivity studies

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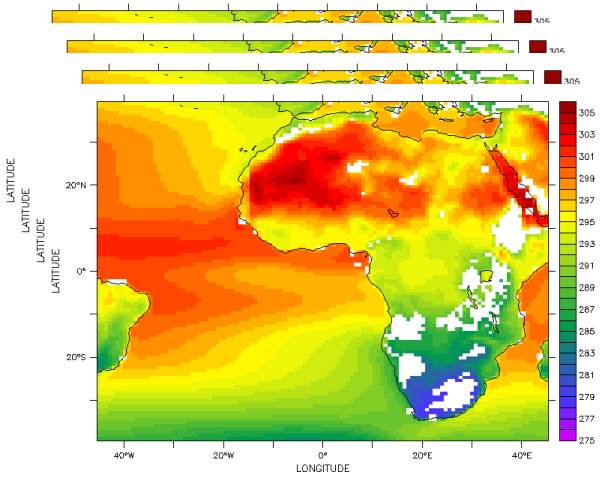
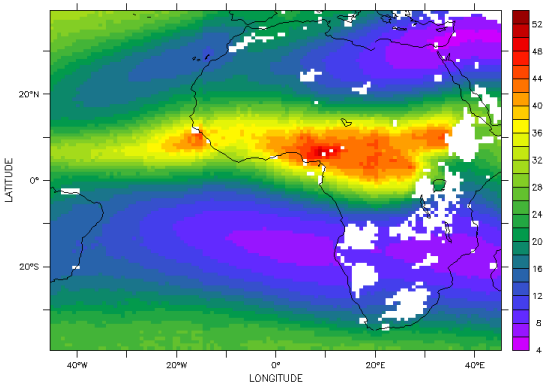
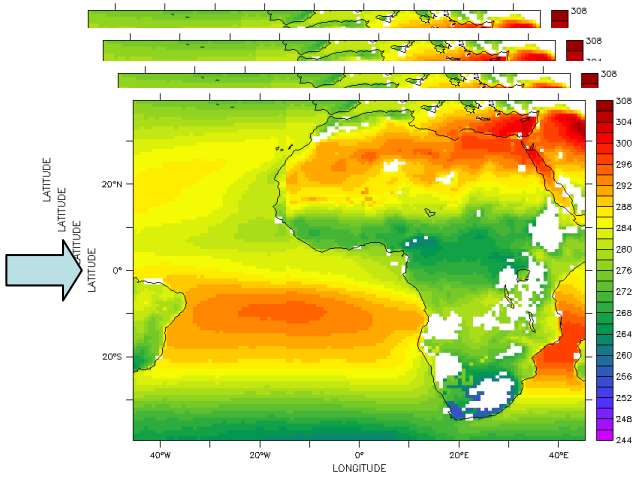


TS field

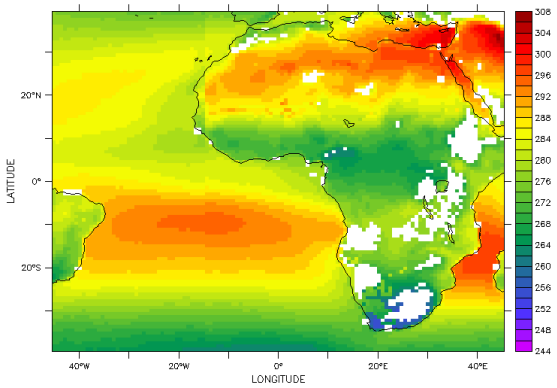


Mean FTH field



- The mean OLRc_fth is computed with no FTH time variability :

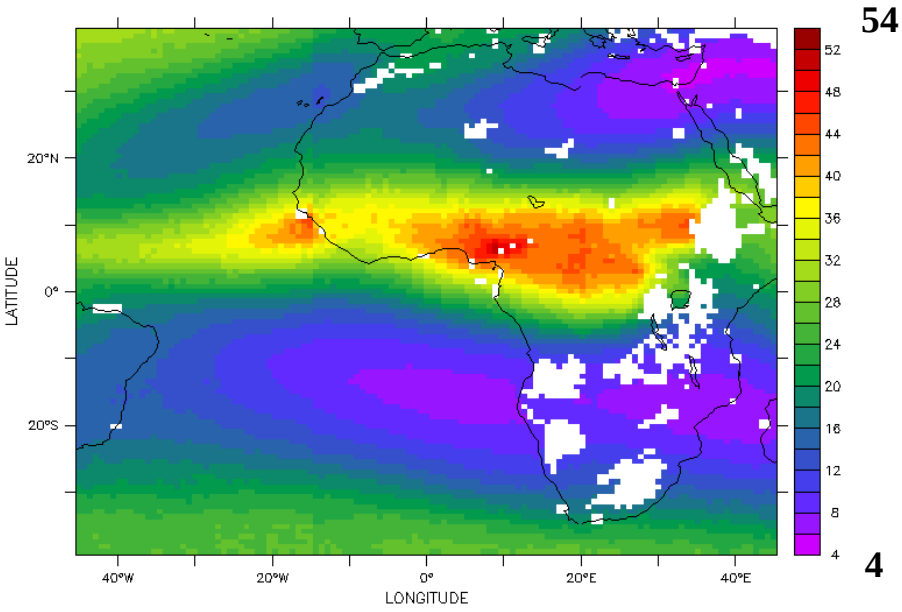
Mean OLRc_fth synthetic field



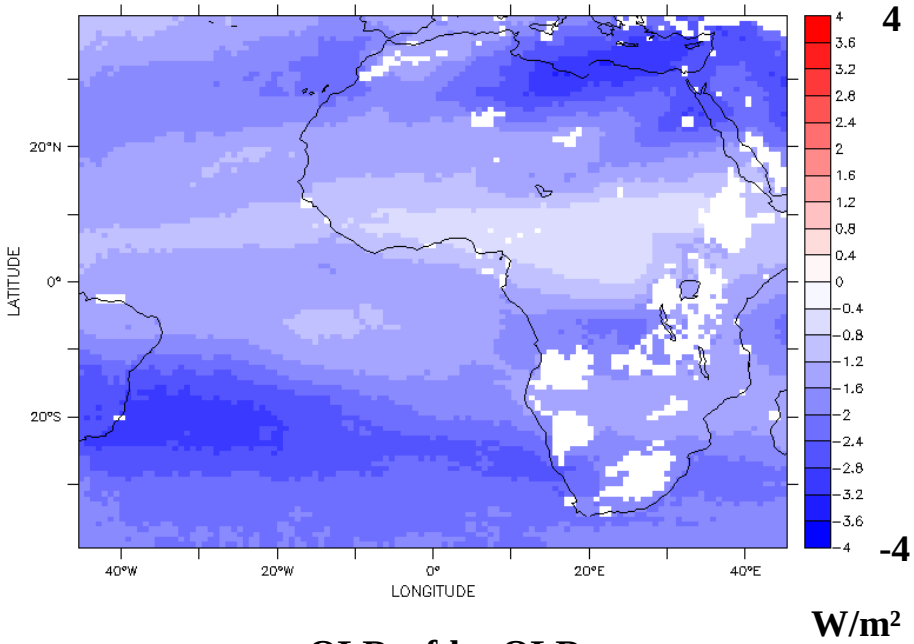
II – OLRc sensitivity studies

II – 2. JJA interannual sensitivity

- For the JJA season, we compute OLRc replacing FTH time variability by its climatology mean value (left). We then map the difference between the means OLRc_fth and OLRc (rifght) in order to evaluate the impact of such experiment. We want to identify where the mean of OLRc is the most sensitive to FTH time variability.



Mean FTH for JJA



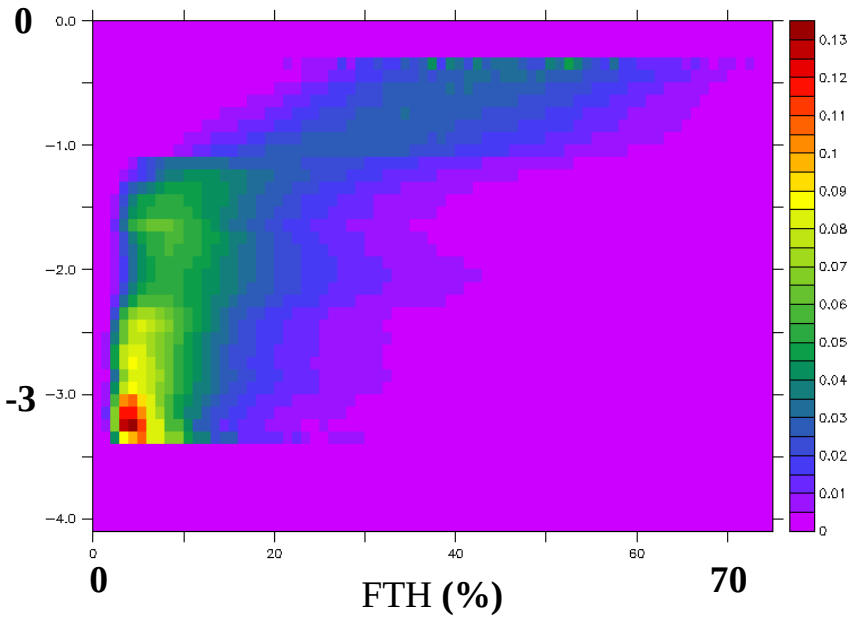
OLRc_fth - OLRc

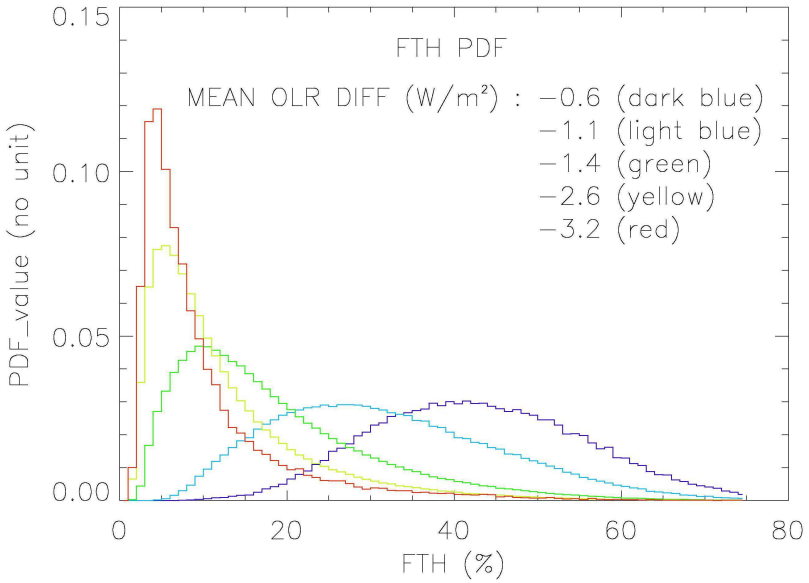
II – OLRc sensitivity studies

II – 2. JJA interannual sensitivity

- (left) 2D distributions of FTH associated to the OLRc_fth minus OLRc anomalies seen on the map and (right) some exemples in 1D (droite). Two FTH regimes are identified : High mean value symmetric FTH PDF have a negligible impact on OLRc mean while asymetric PDF with an important fraction of dry values (FTH < 15%) have a non-negligible impact on OLRc.

DIFF OLRc **(W/m²)**

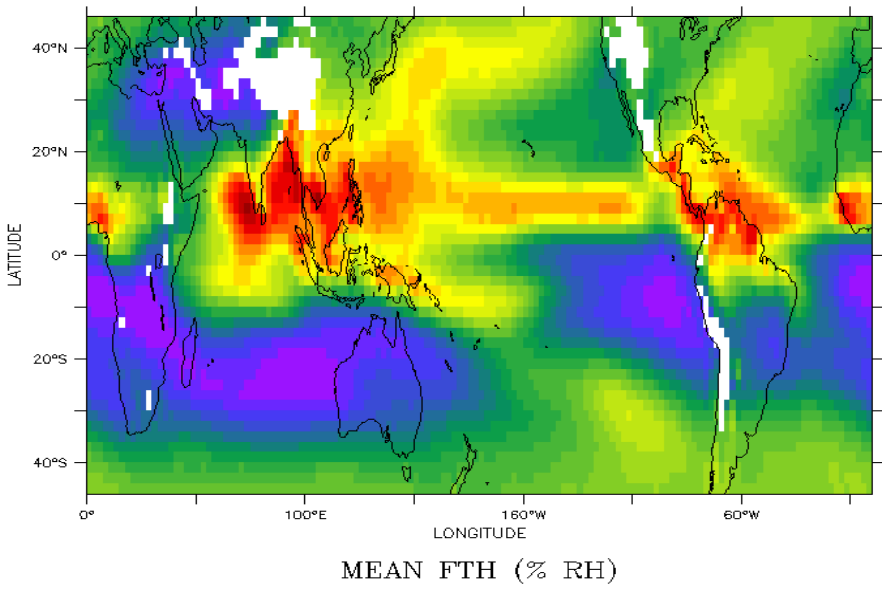




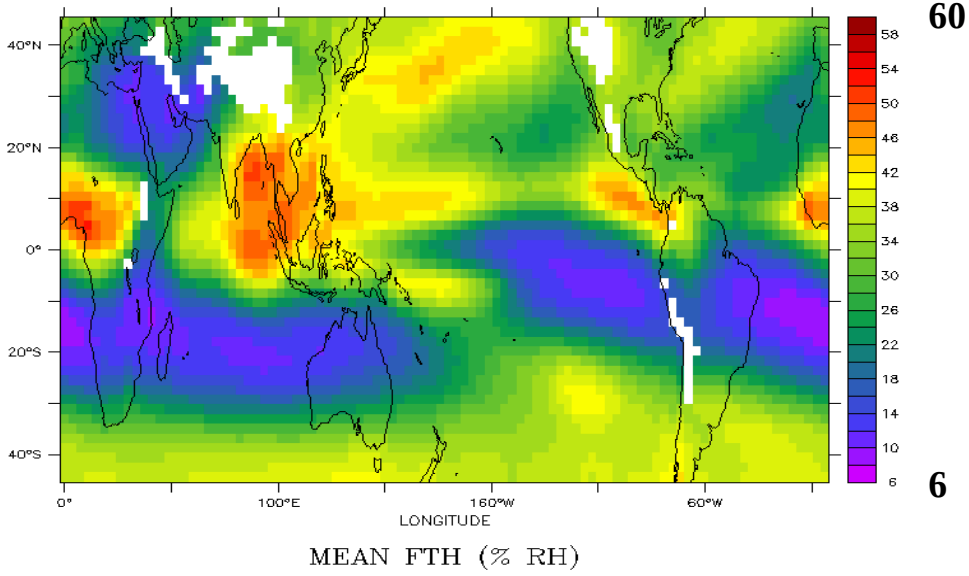
II – OLRc sensitivity studies

II – 3. GCM evaluation

- We want to evaluate this behavior on two GCMs (GISS and IPSL). In order to see if the field variability are well represented, we do the same kind of experiment : We first create the FTH field for each GCM (RTTOV-7), compute OLRc fields with the simple model and do the variability experiment.



GISS-E2-R

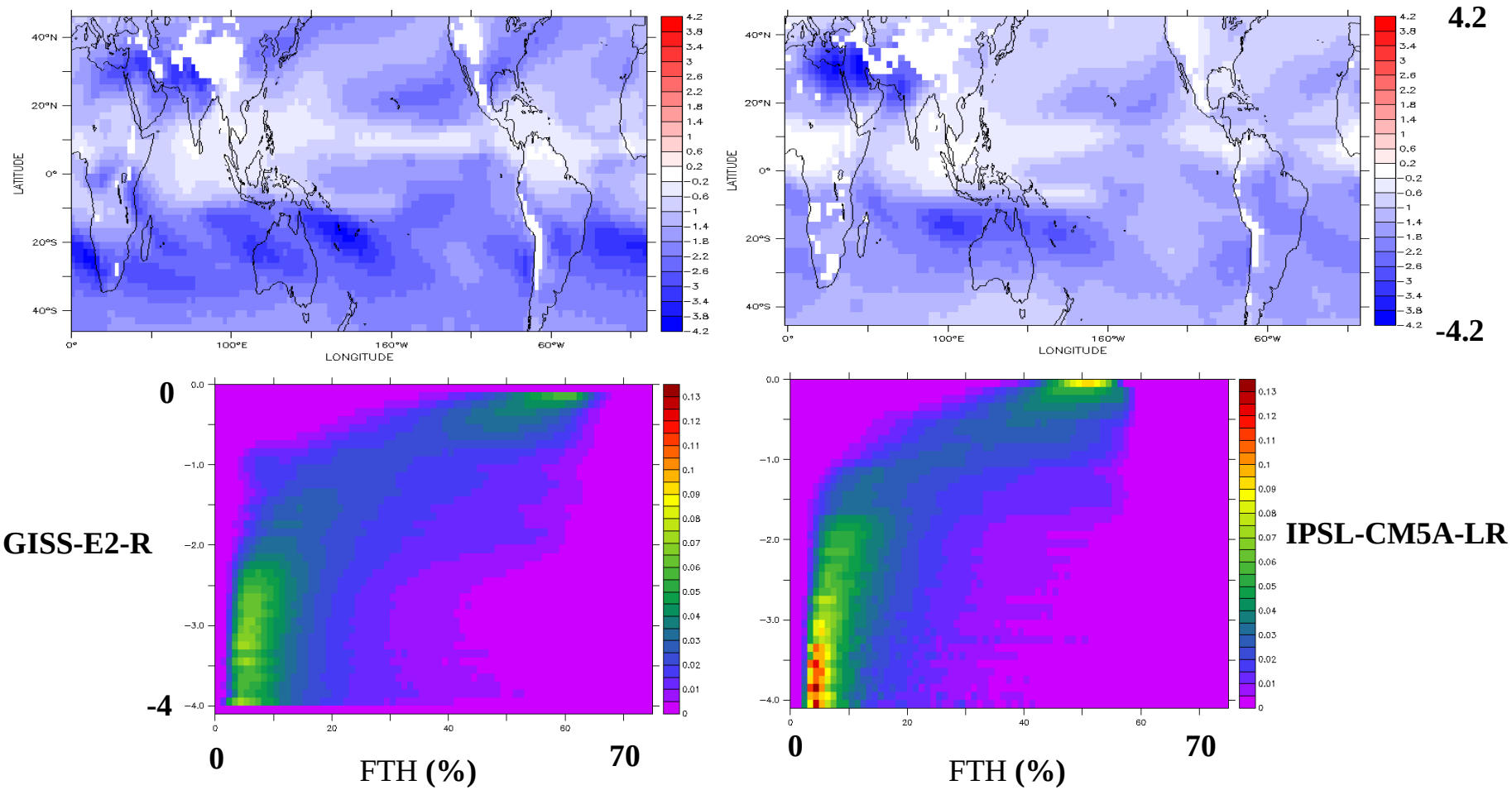


IPSL-CM5A-LR

II – OLRc sensitivity studies

II – 3. GCM evaluation

- JJA season over approximately two decades (1981-2004)

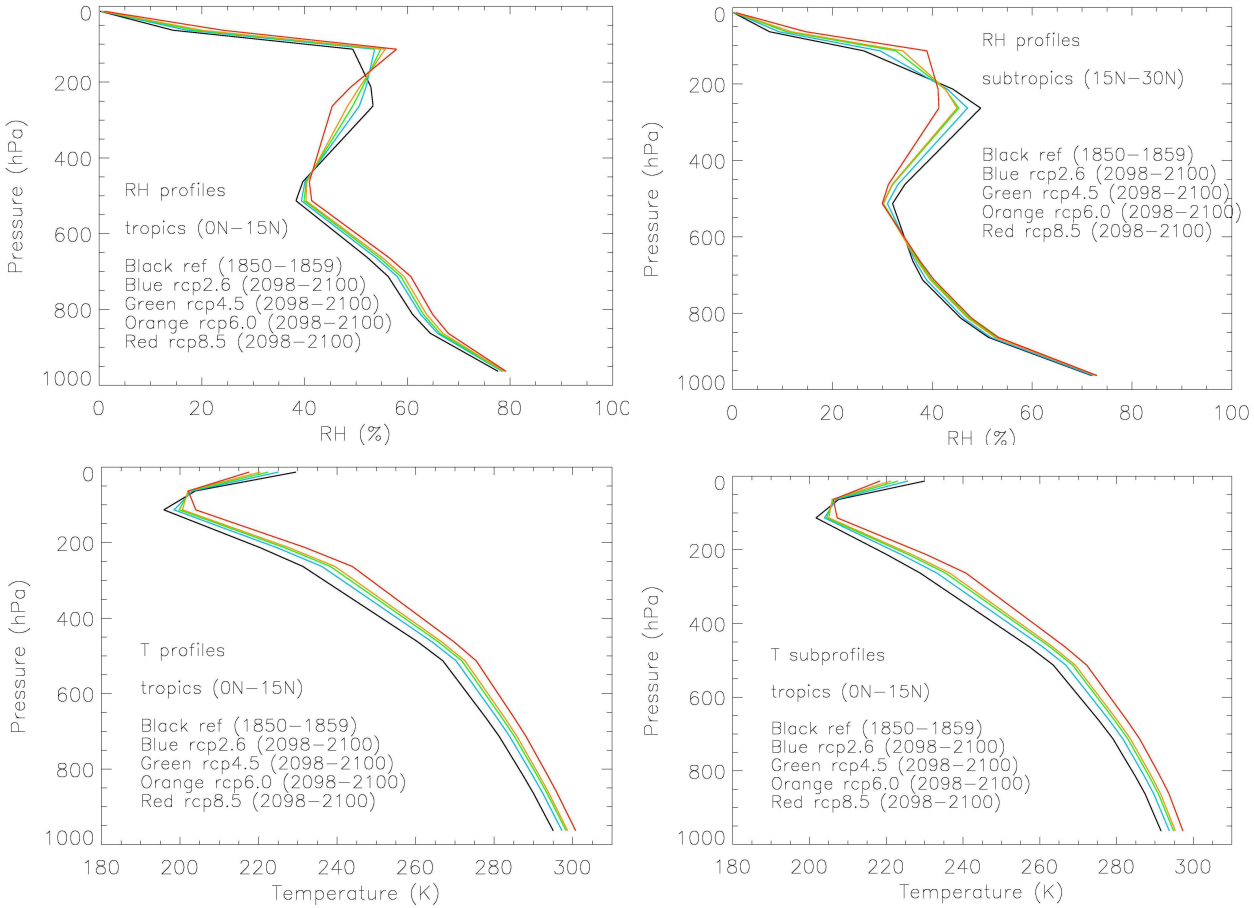


III – OLRc simple model at climate time scales

III – 1. Profiles in the IPSL model

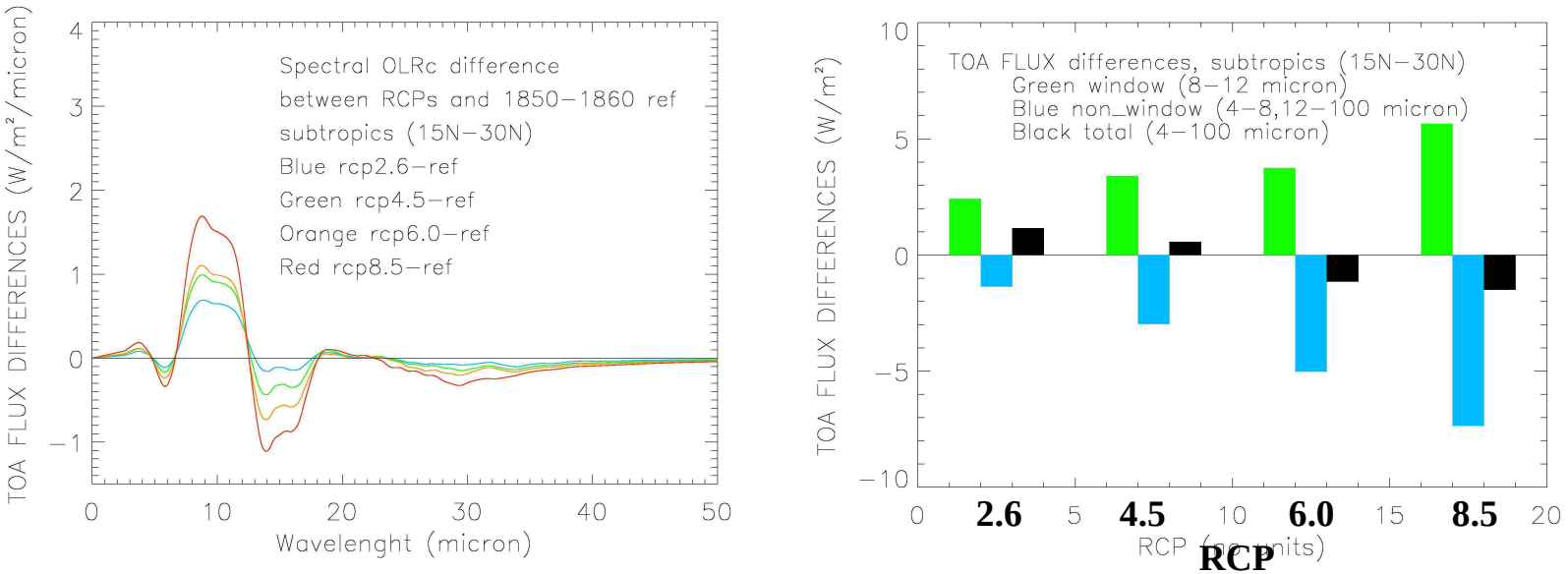
- (top) RH and (bottom) temperature profiles for the pre-industrial and for the four end of the XXIst century scenarios (RCP). (left) Tropical (0°-15N°) and subtropical (15°N-30°N) regions are studied.
The four RCP scenarios: 2.6, 4.5, 6.0, 8.5 W/m² radiative forcing.

Tropics **Subtropics**



III – OLRc simple model at climate time scales

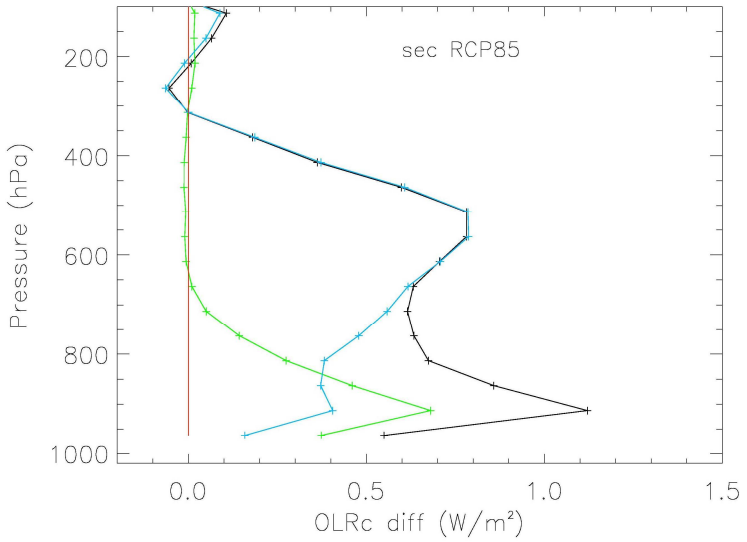
III – 2. Spectral differences between the atmospheric states

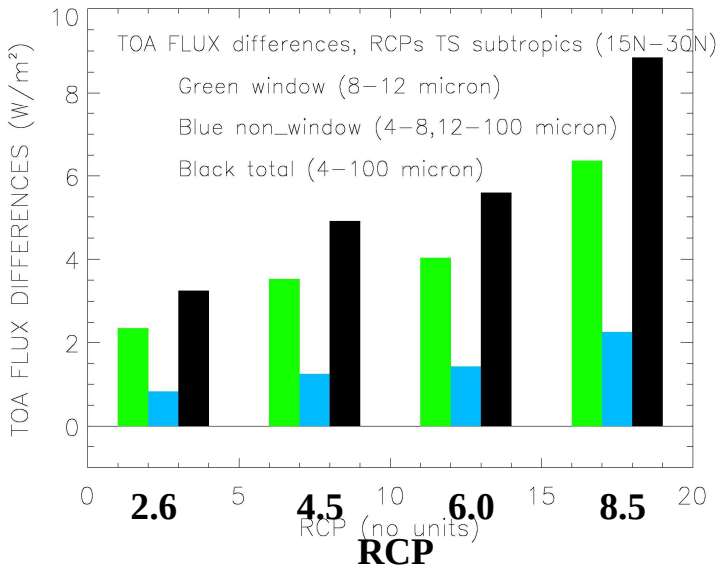


- (left) OLRc spectral differences between the four RCP profiles and the pre-industrial subtropical case. (right) The same differences quantified in the two spectral bands window/non-window. The negative contribution in the non-window is essentially due to the CO2 forcing while the increase in the window flux is the response from the system through higher TS.

III – OLRc simple model at climate time scales

III – 3. Sensitivity at climate time scales





- (left) Vertical sensitivity of the window and non-window spectral band for the subtropical profile computed by simultaneously perturbing each atmospheric layer by the RH and T differences between RCP8.5 (~1350 ppmv CO2) and the pre-industrial reference. (right) Surface sensitivity, only TS perturbations for the same case. The simple model hypotheses seem reasonably satisfied at this time scale as well (TS -> WINDOW / FTH -> NON-WINDOW).

Conclusion/Outlooks

- The development of a simple OLRc model allowed us to show the sensitivity of this radiative field to the PDF of FTH. We quantified the impact on the OLRc mean of replacing by a mean field the full time variability of FTH.

- Two GCMs were studied (GISS and IPSL) and showed a satisfying representation of the variability of the FTH field. This fundamental feature on which depends a correct estimate of the OLRc field is close to what was found for the METEOSAT data.

- The two-parameter model could be used for climate scales studies since the OLRc window and non-window bands are still sensitive to the emission layers associated to FTH and TS at this time scale.

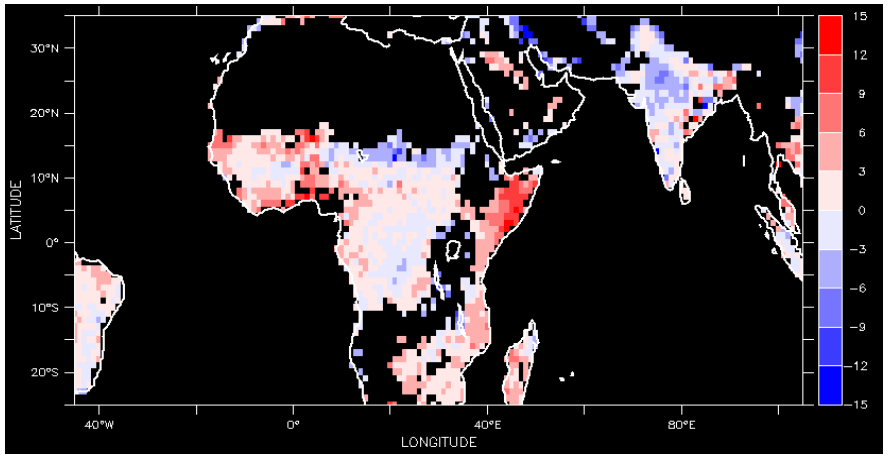
- SAPHIR data will give us FTH and BLH estimates. This will be of great help in order to study the day conditions for the simple OLRc model which seems to need the introduction of such a variable due to the continuum absorption.

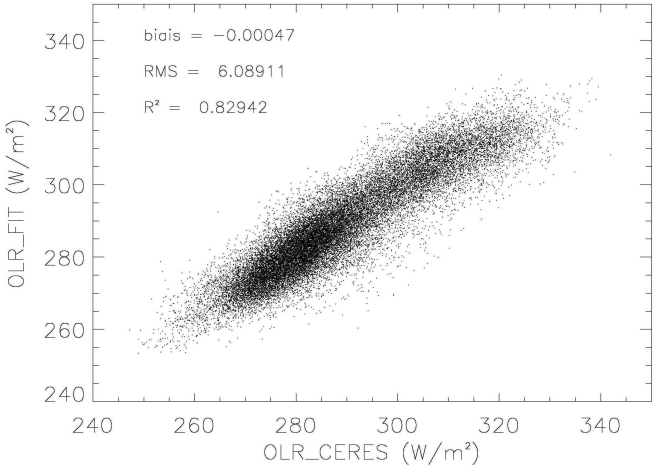
- Developing the simple OLRc model at climate time scales could be an interesting way to investigate different plausible equilibrium states with FTH distributions in a clear-sky radiation-only approach.

Appendix 1

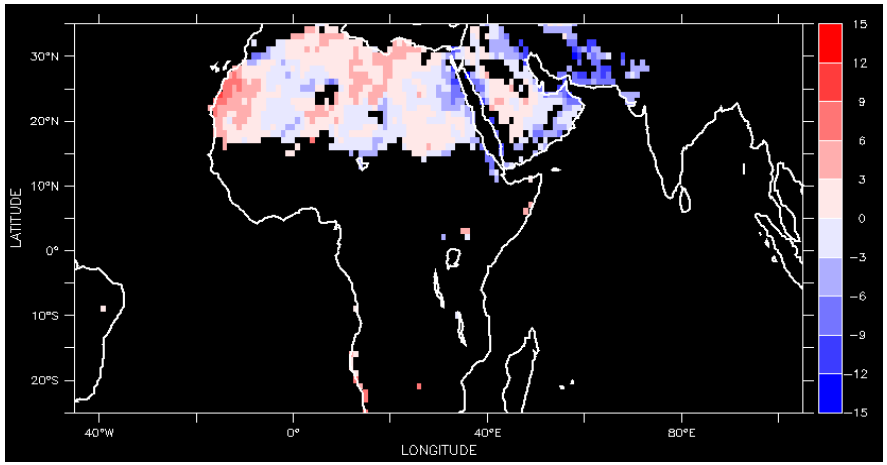
Bilinear regression for nighttime (JJA), 23h-5h:

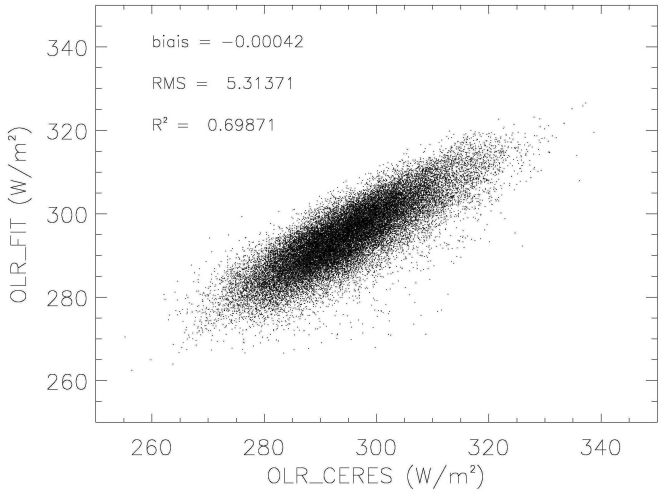
Land :





Desert :

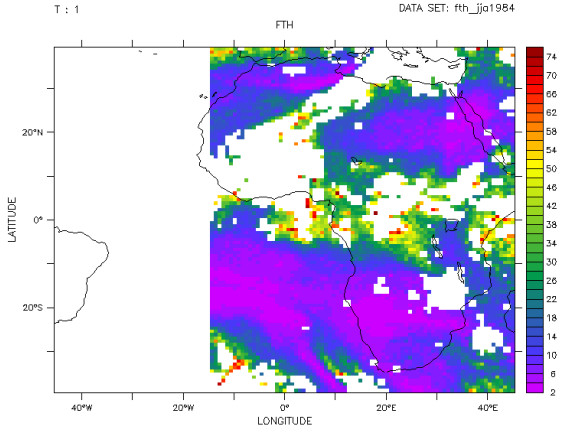




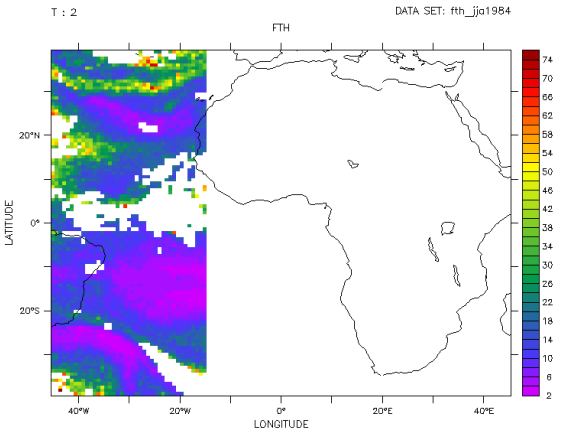
Appendix 2

Sampling for the estimate of OLRc :

METEOSAT nominal (FTH retrieval) :

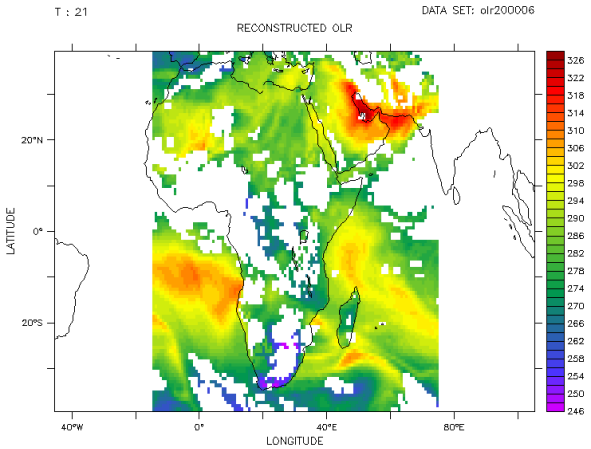


FTH (% RH)

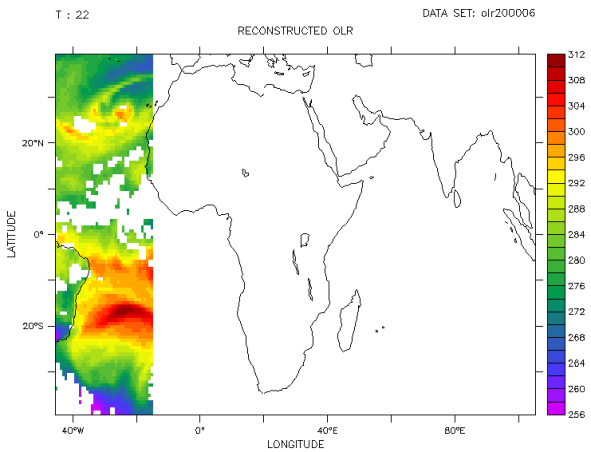


FTH (% RH)

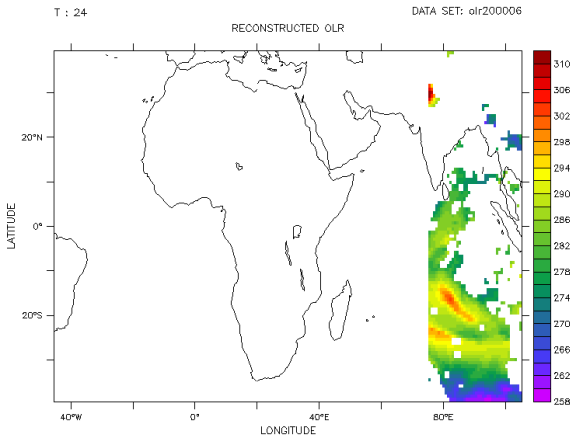
Instantaneous OLRc for the bisat region :



OLR (W/m^2)



OLR (W/m^2)

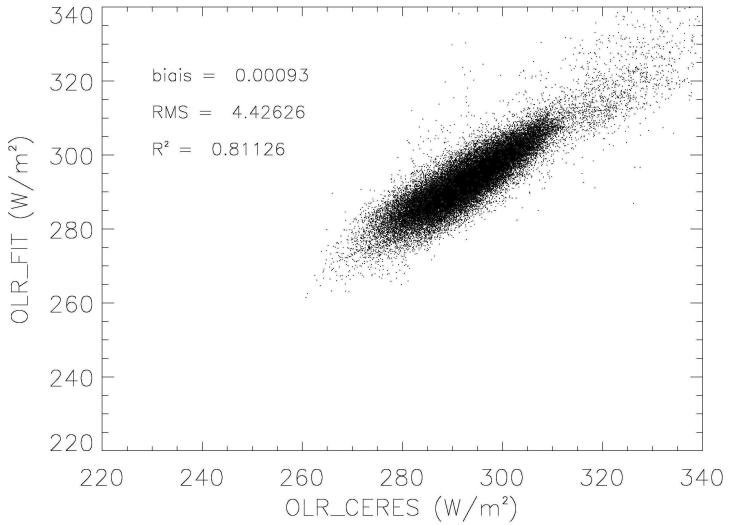


OLR (W/m^2)

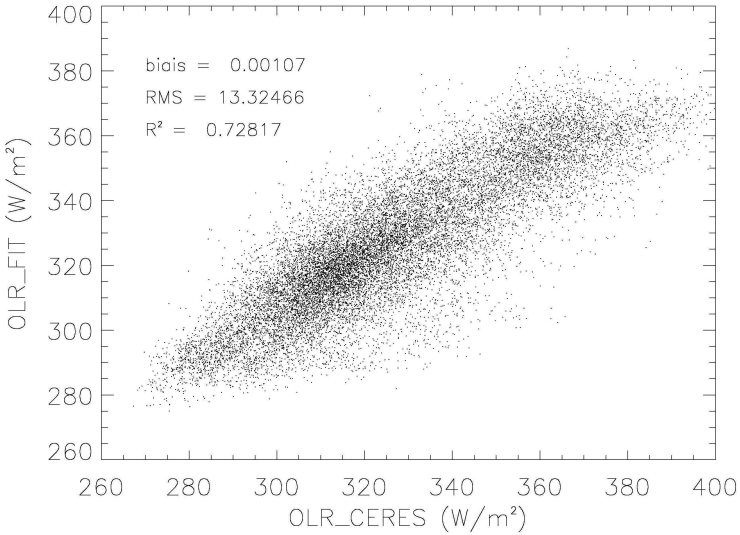
Appendix 3

Bilinear regression for daytime (JJA), 5h-23h:

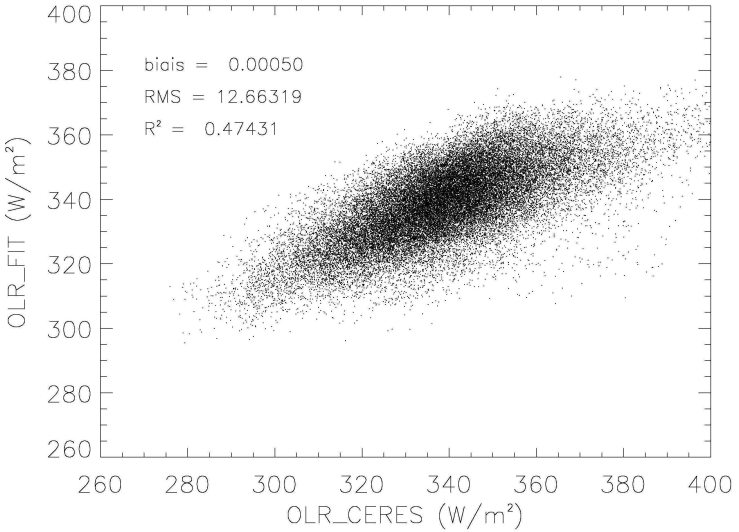
Ocean :



Land :



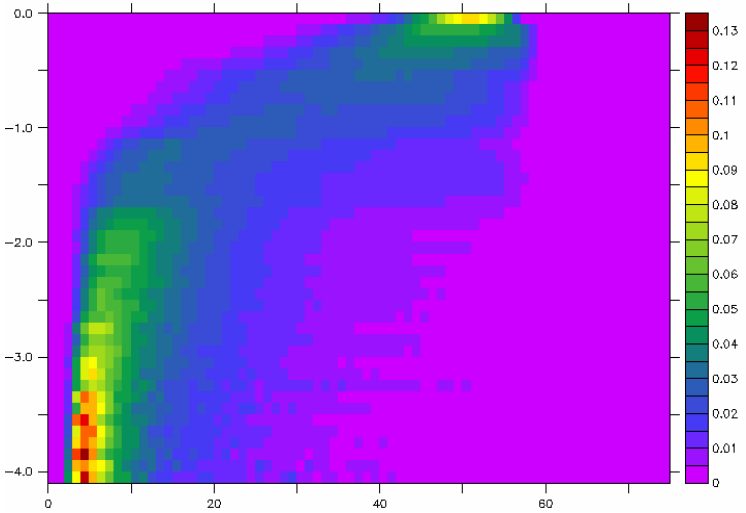
Desert :

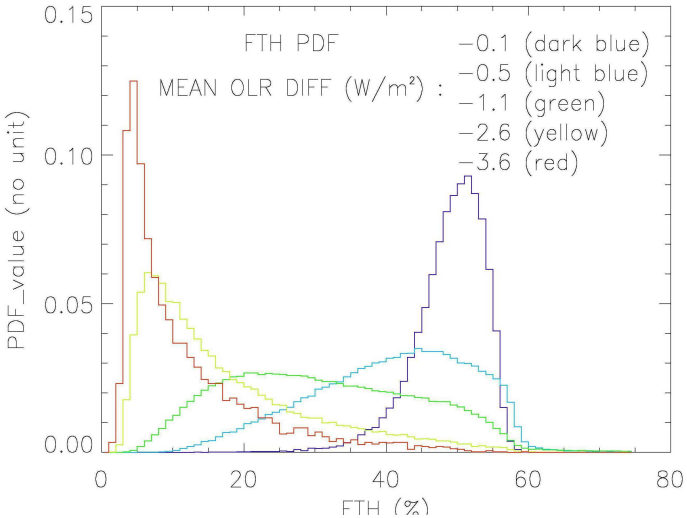


Appendix 4

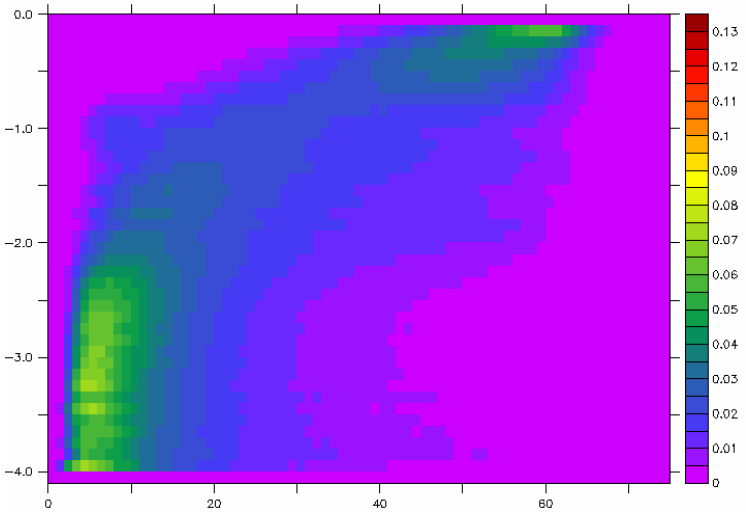
JJA

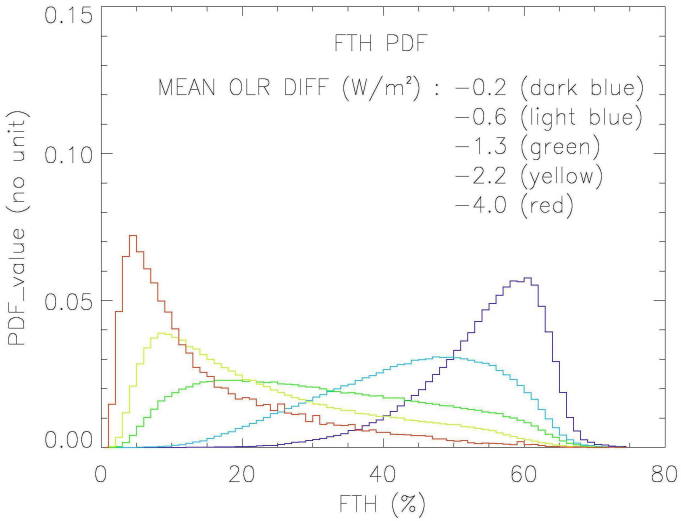
IPSL-CM5A-LR





GISS-E2-R



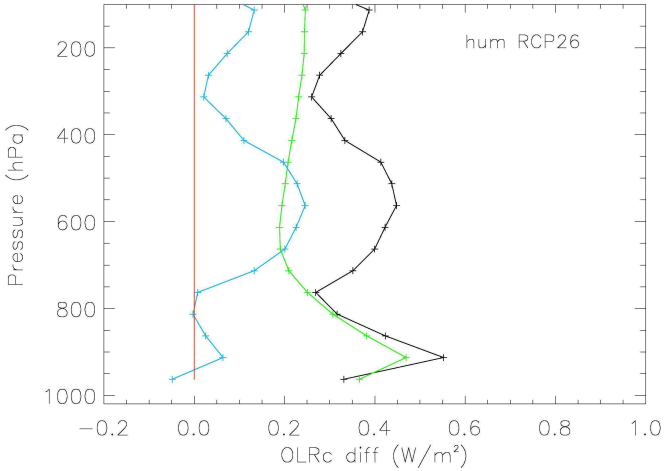


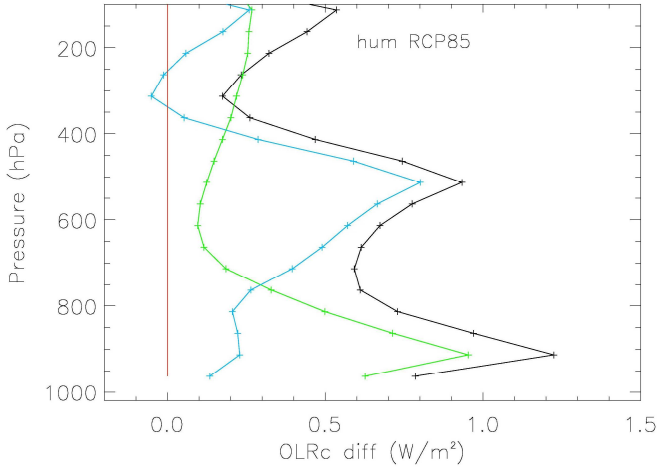
0 FTH **(%)** **70**

Appendix 5

OLRc climate time scale sensitivity in the two bands :

Tropical profile :





Subtropical profile :